BAKING PROPERTIES OF MILK PROTEIN-COATED WHEAT BRAN*

CHARLES I. ONWULATA[1]

Dairy Processing and Products Research Unit
Eastern Regional Research Center
U.S. Department of Agriculture, Agricultural Research Service
600 East Mermaid Lane, Wyndmoor, PA 19038

Accepted for Publication August 15, 2007

ABSTRACT

*Increasing the dietary fiber content of formulated foods will benefit the health and nutrition of consumers. The problem is that it is difficult to add substantial amounts of dietary fiber to formulated foods. Fiber absorbs significant amounts of water from surrounding ingredients creating texture problems such as soggy and dry patches in the foods. In this study, red wheat bran milled and sieved smaller than 140 microns was coated by spraying with a 50/50 emulsion of whey protein isolates (WPIs) and casein. WPI and casein emulsion was produced first by blending and shearing the milk proteins in ice and water and then evaporating under partial vacuum for 75 min at 45C. Cookies and muffins made with the milk protein-coated red wheat (MPCF) bran and the noncoated wheat bran (NCF), replacing 5, 10 and 15 wt % of the flour, were compared to control cookies and muffins made without added fiber. The water-holding capacity (WHC) of the MPCF and NCF was determined along with their moisture, color, hardness, and volume in the baked cookies and muffins. There was a significant (*P *< 0.01) improvement (250%) in loss of WHC of MPCF over NCF. In cookies, MPCF absorbed significantly less water and was slightly darker at 5 wt % substitution than NCF, but was between 12 to 60% higher in baked volume than the control. MPCF muffins were lighter in color and harder except for the 5 wt % muffins that were softer and higher in percent baked volume. Adding up to 15-g MPCF per 100 g batter can be added to baked cookies and muffins to increase fiber content and improve WHC and volume.*

* Mention of trade names or commercial products is solely for the purpose of providing specific information and does not imply recommendation or endorsement by the U.S. Department of Agriculture.

[1] Corresponding author. TEL: 215-233-6497; FAX: 215-233-6470; EMAIL: conwulata@errc.ars.usda.gov

Journal of Food Processing and Preservation **32** (2008) 24–38.

PRACTICAL APPLICATIONS

This study determined that coating wheat bran with specially treated dairy proteins reduced the amount of water the bran can absorb when added up to 15 wt% to formulations, or in the finished products, helping to maintain textural integrity of products. The intact wheat bran remains available for its functional health enhancing roles when consumed and digested. This knowledge allows the creation of nutritious high-fiber products with desirable texture.

INTRODUCTION

As the reports of the nutritional and health benefits of consuming dietary fibers continue to grow, effort is focused on increasing the amount, content and quality of fibers in human diet. Consumers as well as nutrition-focused professional organizations are demanding increased amounts of fiber in processed foods. The results of surveys of the amount of fiber consumed by Americans reveal that many consume less than the estimated desirable daily fiber intake. The American Dietetic Association recommends 20–35 g/day (American Dietetic Association Position Statement 1993), but a recent survey of dietary fiber intake levels reports a median of 16.5 to 17.9 and 12.1 to 13.8 g/day for men and women, respectively (Slavin 2005a).

Foods rich in fiber help with the management of a host of health conditions. Associated healthful benefits of increasing fiber consumption include reducing the risk of some types of diseases such as breast cancer and coronary heart disease; regulating blood glucose and insulin; lowering the concentration of blood lipids; reducing the risk of cardiovascular disease; controlling diabetes; alleviating constipation, hemorrhoids and diverticulitis; and managing weight (Kritchevsky 1977; Wolk *et al.* 1999; Slavin 2005b).

Though it is desirable and beneficial to increase the amount of fiber in most foods, there are considerable food processing difficulties associated with increasing the levels of dietary fiber (DF) in manufactured foods. Increasing the amount of DF in foods alters the textural properties of foods (Vratanina and Zabik 1978). DFs tend to absorb and withhold water from their surrounding environment, creating localized pockets of high moisture and very dry areas in foods fortified with DF, thereby increasing their overall water-holding capacity.

DF incorporated into foods absorbs water from the other components, making the surrounding food components dry and brittle, especially the insoluble fibers. Adding 5 to 15 g/100 g of commercial DF from sugarcane bagasse to wheat flour decreased textural properties and sensory quality of wheat bread (Sangnark and Noomhorm 2004). Zhang and Moore (1997) observed that increasing the level of unmodified insoluble DF in foods destroyed the textural integrity by interspersing and breaking cohesive food networks. For example, insoluble DF from wheat bran incorporated into wheat bread resulted in reduced volume (Lai *et al.* 1989). Large amounts of insoluble fibers cannot be used in foods such as drinks, yogurt or in unmodified pasta (Brennan *et al.* 2004; Dello Staffolo *et al.* 2004).

Current levels of insoluble DF fortification in breads and cookies on the market are less than 3%. Fiber levels in foods could be increased a hundred fold if their water-holding capacity potential were reduced. Sangnark and Noomhorm (2003) reported that an effort to fortify wheat bread with unmodified insoluble dietary at levels between 5 to 15 g/100 g resulted in significantly decreased expansion, stickiness of dough, as well as decreased loaf volume, specific volume, firmness, springiness and sensory acceptance. Modifying the property of insoluble wheat bran by coating with specially linked milk proteins would reduce its water-binding property and allow for incorporating specially modified DF into foods in large quantities in baked goods such as cookies and muffins without significant adverse textural effects. Therefore, the objective of this study was to determine the physical and textural property effects of using milk protein-coated wheat bran to fortify cookies and muffins.

MATERIALS

Coarse stabilized red wheat bran (product number: 02-12-RC) was purchased from Canadian Harvest Process, Ltd. (Ontario, Canada). Calcium caseinate (Alanate 391) and whey protein isolate (Alacen 895) were purchased from New Zealand Milk Products, Inc. (Santa Rosa, CA). The proximate compositions of the materials were as follows: wheat bran, moisture 5.6%; protein, 17.2%; total DF, 53.9% (insoluble fiber, 51.0% and soluble fiber, 2.9%); calcium caseinate, protein, 92.0%; moisture 4.0%; ash, 3.4%; fat, 1.2%; and lactose, 0.3%; whey protein concentrate, protein, 94.0%; moisture 3.9%; ash, 1.6%; fat, 0.5%; and lactose, 0.5%.

METHODS

Protein-Coated Wheat Bran

The red wheat bran was sieved and particles that passed through a 140-micron sieve were coated and used for the baking studies. The calcium caseinate/whey protein isolate (50/50, w/w) emulsions were prepared through a caseinate dispersion method (Strange and Konstance 1991). The 50/50 calcium caseinate/whey protein isolate slurries were prepared using 10 g of calcium caseinate and 10 g of whey protein isolate. The 20 g of milk proteins was mixed with 320 g of finely crushed ice in a blender for 24 s, using a Waring Lab Micronizer (Waring Products Division, New Hartford, CT). The milk proteins and ice mixture blend were dissolved in 800 mL deionized water. The milk protein slurries were blended using a PCU-2 high shear homogenizer (Brinkman Instruments, Westbury, NY) for 4 min. The homogenized protein slurries were evaporated to form milk protein gels by heating at 45C under partial vacuum (5.2 MPa) in a Rotary Evaporator Model RE-52 (Yamata Scientific Co., Ltd. Tokyo, Japan) for 75 min. Aliquots of milk protein gels (~180 g) were collected after evaporation. This procedure was repeated until 1 L of milk protein gel solution was obtained. Moisture content of the milk protein gels was determined immediately using a Sartorius Moisture Analyzer MA51 (Edgewood, NY). To create milk protein-coated DF, 4 g of stabilized red wheat bran with particle size less than 150 microns was mixed with 100-g milk protein gel (11% solids) and spray dried in a Niro Atomizer (APV Niro, MA). The wheat bran and milk protein gels were atomized at 25,000 rpm and dried with inlet/outlet temperatures of 208/102C. The milk protein-coated fiber (MPCF) powder was collected and stored at 4C.

Baking Studies

Formulations. Sugar-snap cookies (AACC 1983) and muffins were selected for our baking trials. MPCF or noncoated wheat bran (NCF) was substituted weight-for-weight for flour in the modified formulations listed in Table 1. Formulations are presented on a flour basis. Crisco (Church & Dwight, Princeton, NJ) served as the vegetable shortening for all control formulations. Fluid whole milk (3.2% milk fat), fresh eggs, double-acting baking powder (Rumford, Church & Dwight), baking soda (Arm & Hammer, Church & Dwight), salt and vanilla were purchased at a local supermarket. Glucose solution (5.6%) was prepared from glucose powder and water. A 4.4-L mixing bowl (Kitchen Aid Model K5SS, Hobart, Troy, OH) was used for all dough preparations. Metal or plastic gauge strips were prepared to fit a polyethylene cutting board or metal cookie sheet to control thickness of the rolled dough. All products were baked in a Despatch Rotary Oven Model 150 (Despatch Industries, Inc., Minneapolis, MN) equipped with a single revolving shelf.

Cookies. Sugar, salt, baking soda and shortening were creamed 3 min on the low setting of the mixer. Glucose solution was added and the mixture blended for 1 min. Flour mixed with MPCF or NCF was added and the dough

TABLE 1.
FORMULATIONS FOR COOKIES AND MUFFINS*

Ingredients	% MPCF or NCF			
	Cookies†			
	Control	5	10	15
All purpose flour	100	95	90	85
Sucrose	57.8	—	—	—
Vegetable shortening	28.4	—	—	—
Dextrose solution	14.7	—	—	—
Water	13.3	—	—	—
Vanilla extract	2.7	—	—	—
Baking soda	1.1	—	—	—
Salt	0.9	—	—	—
Wheat bran	—	5	10	15
	Muffins‡			
All purpose flour	100	95	90	85
Fluid whole milk	75.6	—	—	—
Whole egg	26.0	—	—	—
Sucrose	21.1	—	—	—
Vegetable shortening	21.1	—	—	—
Water	8.3	—	—	—
Baking powder	4.3	—	—	—
Salt	2.1	—	—	—
Wheat bran	—	5	10	15

* Three batches of each formulation were prepared. All formulations are on flour basis; to formulate a full batch, multiply recipe with conversion factors 2.42 and 2.25, for cookies and muffins, respectively. All formulations contain baking soda, salt, dextrose solution and vanilla at levels of 1.1, 0.9, 14.7 and 2.7%, respectively, flour basis. Vegetable shortening was melted before blending into the dough.

† Baking at 230C for 10 min.

‡ Baking at 230C for 35 min.

was blended until a ball formed (about 30 s). Cookie dough was turned out onto a greased cookie sheet and rolled to a thickness of 0.70 cm, using gauge strips. Circles of 7.0-cm diameter were cut out and the excess dough lifted away from the cookies which were then baked at 230C for 15 min. Baked cookies were cooled to ambient temperature on wire racks, measured to calculate mean diameter and height, packed and stored as reported previously. Eight cookies were obtained per batch; three replicates were prepared.

Muffins. Dry ingredients were blended for 1 min. Liquid ingredients were added, blended for 15 s, scraped down with a spatula and blended for another 15 s. Sixty-eight grams of aliquots was scaled into nine holes, each 6.4 cm in diameter, of a 12-hole muffin tin previously sprayed with a flour–oil mixture. Sixty milliliters of water was measured into each empty hole. Muffins were baked at 230C for 24 min. Muffins were cooled briefly in the pans, turned out on wire racks and cooled to ambient temperature. The muffins were packed in a single layer in freezer bags and stored frozen until analyzed. Nine muffins were obtained per batch. Three batches were prepared for analysis.

Physical Determinations

Moisture content was determined as per Method #925.09 (AOAC 2000), using a vacuum oven. Water-holding capacity tests were completed on the fibers before and after coating. Two grams of both wheat bran products was placed in centrifuge tubes. Twenty milliliters of distilled water was added to the tubes and stirred with the fibers. After standing for 20 min, the tubes were centrifuged using Sorvall Instruments EconoSpin (Dupont Instruments, Wilmington, DE) for 5 min at 25C. Afterward, the excess water was discarded and the tubes inverted an additional 5 min. The tubes were weighed and water-holding capacities calculated as follows: ([weight gain of fiber/dry weight] × 100).

Protein content of cookies and muffins was determined using the FP-2000 nitrogen analyzer (LECO Corporation, St. Joseph, MI). A protein conversion factor of 5.70 × N was used.

Color measurements of cookies and muffins were evaluated instrumentally with a Gardner infrared spectrophotometer Model TCM (BYK-Gardner, Inc., Silver Spring, MD) equipped with illuminant A. Calibration values were *L*, 98.34; *a*, –0.21; *b*, 0.19. Hunter *L*, *a* and *b* values were obtained directly from quadruplicate measurements. Specimens were rotated 90C after each observation.

Mean particle size distribution of the control and milk protein-coated wheat bran specimens was determined. Each specimen was analyzed using the Accusizer Optical Particle Sizer model 770 (Particle Sizing Systems, Santa Barbara, CA).

Mechanical Testing. Instrumental texture profile analysis of cookies and muffins was performed at 25C with an Instron Universal Testing Machine Model 4201, (Instron, Inc., Canton, MA) equipped with either a 50- or 500-N compression load cell. Specimens were compressed at a crosshead speed of 10 cm/min. The Instron Cyclic Foam Compression Test Software was used for data acquisition and control during the tests. Force–time curves were analyzed for hardness, springiness and cohesiveness as described by Bourne (1978). In preparation for testing, muffins were returned to their tins while frozen and the tops sliced off evenly. Plugs 30 mm high × 48 mm in diameter were cut from the centers of the muffins while frozen with a metal cylinder. Specimens were wrapped tightly in plastic wrap and equilibrated to room temperature for 2 h before texture analysis, where the cores were compressed to 40% of their original height. Whole cookies were compressed to only 20% of their height. Thickness and diameter were determined with a vernier caliper (four measurements, rotating 90°/per specimen). Four replicates were prepared.

Volume Measurements. Volume displacement was taken as the primary indicator of baking performance for cookies and muffins. The volumes, determined by glass bead displacement in a 500-mL plastic container, were taken 24 h after baking. The specific volume of the glass beads used was 0.654 cm^3/g. Displaced volume was determined for eight specimens of each of the three replicates of cookies and muffins (24 determinations of each product).

Freshly thawed wheat bran cookies and muffins (about 1–2 mL each) were cut and dialyzed against 10 mL of 5% glutaraldehyde in 0.1 M imidazole HCl buffer (pH 7.0) 12 h at RT. Specimens of Whey Protein Concentrate (WPC) were removed from tubing (small specimen held aside in glutaraldehyde for embedding/thin sectioning) and washed in imidazole buffer. Specimens were dehydrated for 12 h in 50% ethanol and absolute ethanol, and immersed in liquid nitrogen. Specimen fragments in nitrogen were removed and quickly thawed in ethanol and stored overnight. The next day, specimens were critical point dried in carbon dioxide, mounted on aluminum stubs with colloidal silver adhesive, and sputter coated with a thin layer of gold and examined in scanning electron microscope (Model JSM840A, JEOL USA, Peabody, MA) operated in the secondary electron imaging mode at an instrumental magnification of 10,000×. Digital images were collected with an Model IMIX1 workstation (Princeton Gamma-Tech, Princeton, NJ).

RESULTS

Moisture, particle sizes and water-holding capacity of NCF and MPCF are presented in Table 2. The mainly significant difference ($P < 0.01$) in the physical properties was in the water-holding capacity of wheat bran, dramatically reduced (>250%) by applying a milk protein coating. Other significant differences were the reduction in particle size, and changes in shape of the MPCF particles (Fig. 1), perhaps because of the shear force of atomizing (25,000 rpm) wheat bran fibers through a 2-mm-orifice atomizer.

TABLE 2.
PHYSICAL PROPERTIES OF UNCOATED WHEAT BRAN AND MILK PROTEIN-COATED WHEAT BRAN

Product	Moisture (%)	Mean particle size (μm)	Water-holding capacity (%)
Wheat bran	2.3	13.7	226
	(0.5)	(1.2)	(2.0)
Protein-coated bran	6.5	7.6	64
	(0.5)	(1.2)	(1.5)

Numbers underneath with brackets are SDs.

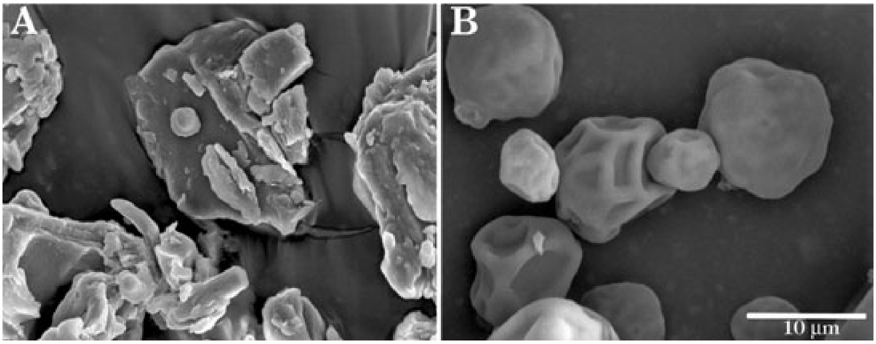

FIG. 1. SCANNING ELECTRON MICROGRAPHS OF UNCOATED WHEAT BRAN (A) AND MILK PROTEIN-COATED WHEAT BRAN (B)

Cookies

The physical properties of the cookies made with NCF or MPCF are presented in Table 3. Cookies with NCF were typically higher in moisture than the control except for an anomaly, 10 wt % NCF. In general, cookies made with NCF or MPCF were high in moisture. But mostly, MPCF cookies contained more moisture than NCF. At the elevated wheat bran content, the MPCF cookies had high moisture content. Cookies are generally low-moisture products and overall moisture ranged only from 6.1% control, to 15 wt % MPCF at 10.1; the mean was 7.6%.

Cookies made with MPCF contained 14 to 45% more protein compared to those with ordinary wheat bran as a result of the protein coating process.

The total color difference of the cookies baked with MPCF was smaller than the control; low total color difference indicates darker color. High total color difference, ΔE, indicates lighter color. Generally, the protein-coated wheat bran cookies were darker than either control or the NCF. Darker cookies

TABLE 3.
PROPERTIES OF COOKIES CONTAINING THREE LEVELS OF UNCOATED WHEAT BRAN AND MILK PROTEIN-COATED WHEAT BRAN

	Moisture %	Protein %	Color ΔE	Hardness N	Displaced volume cm^3
Control	6.1	6.4	50.5	18.5	21.7
5	8.8	6.5	48.8	11.2	20.6
10	5.9	6.4	49.7	32.5	18.7
15	7.6	6.8	49.7	33.7	11.1
			Milk protein-coated fiber		
5	7.5	7.3	46.0	25.8	24.2
10	7.3	8.7	47.8	37.4	23.3
15	10.1	9.3	48.0	33.2	17.8
PSD	1.0	0.3	1.2	1.6	1.7

PSD, pooled standard deviation.

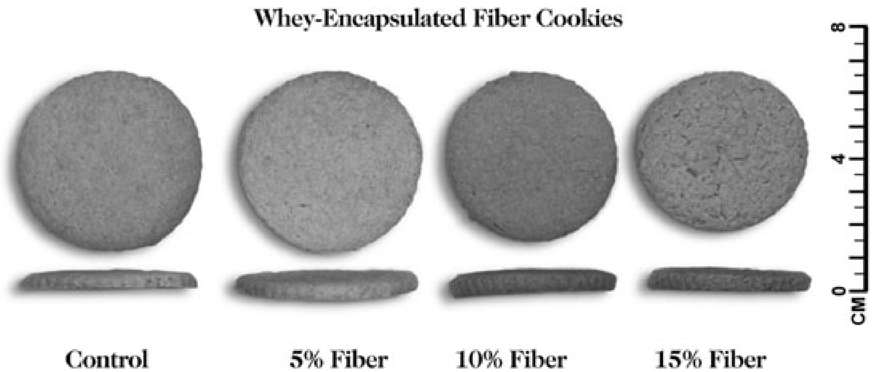

FIG. 2. PHOTOGRAPHIC IMAGE OF COOKIES BAKED WITH UNCOATED WHEAT BRAN (CONTROL) AND THREE SELECTED AMOUNTS OF MILK PROTEIN-COATED WHEAT BRAN

may reflect browning because of Maillard-type reactions with whey proteins and sugars.

Cookies containing wheat bran were harder than the control, except for 5 wt % NCF, which was softer. Naturally, the inclusion fiber changes textural properties. In this study, inclusion of wheat bran increased hardness of cookies.

Baked cookie volume is an important indicator of ingredient performance and subsequent acceptance by consumers. As the content of wheat bran increased, the volume of the baked cookies decreased (Fig. 2). At 5, 10 and 15% added bran, decreases of 5, 14 and 49% in the volume were observed. MPCF cookies increased in volume over both the control and NCF, being

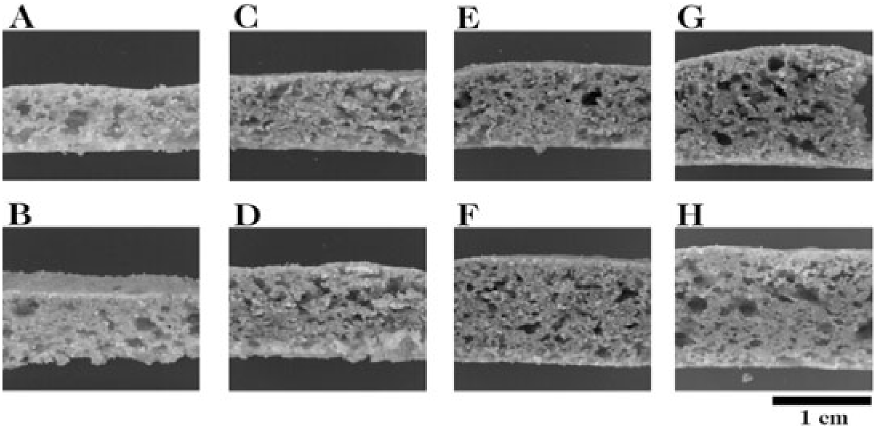

FIG. 3. PHOTOGRAPHIC IMAGE OF COOKIES BAKED WITH UNCOATED WHEAT BRAN (CONTROL) AND THREE SELECTED AMOUNTS OF MILK PROTEIN-COATED WHEAT BRAN, SHOWING DIFFERENT HEIGHTS AND PORES

approximately 12% larger in volume than the control and 17% larger in volume than the NCF. However, displaced volumes for the protein-coated wheat bran cookies were smaller as the amount of NCF added increased. Comparing cookie volume at 15 wt % fiber level, MPCF cookies were 60% larger in volume than the cookies containing uncoated bran (Fig. 3).

Muffins

Physical properties of muffins containing selected amounts of NCF or MPCF are presented in Table 4. The moisture content of muffins containing the coated and uncoated wheat bran was larger than of the control, but the moisture content of muffins made with the MPCF was smaller than the moisture content of the NCF muffins, and was significantly ($P < 0.05$) smaller at 10 wt % MPCF than NCF. Moisture uptake was uniformly large, but the reduction in moisture uptake with the MPCF was significant ($P < 0.05$). With muffins, a higher moisture product than cookies, the effect of milk protein coating on moisture becomes more apparent (Fig. 4).

The protein content of the wheat bran muffins was only slightly larger than of the control muffins. Muffins containing the MPCF were larger in protein content as the MPCF cookies were, reflecting the added protein from the coating process.

Total color difference varied with the muffins at the selected amounts of wheat bran added. At 5 and 10 wt % respectively, the wheat bran muffins were

TABLE 4.
PROPERTIES OF MUFFINS CONTAINING THREE LEVELS OF UNCOATED WHEAT BRAN AND MILK PROTEIN-COATED WHEAT BRAN

	Moisture %	Protein %	Color ΔE	Hardness N	Displaced volume cm^3
Control	36.4	6.9	46.7	1.6	73.9
5	40.2	7.4	35.8	1.4	89.5
10	40.7	7.1	45.2	1.8	77.0
15	40.1	7.5	49.7	2.0	80.8
		Milk protein-coated fiber			
5	38.7	8.2	50.2	1.4	85.4
10	36.6	8.5	31.8	1.9	85.4
15	38.1	9.5	70.9	2.0	79.5
PSD	1.4	0.4	1.4	0.5	2.2

PSD, pooled standard deviation.

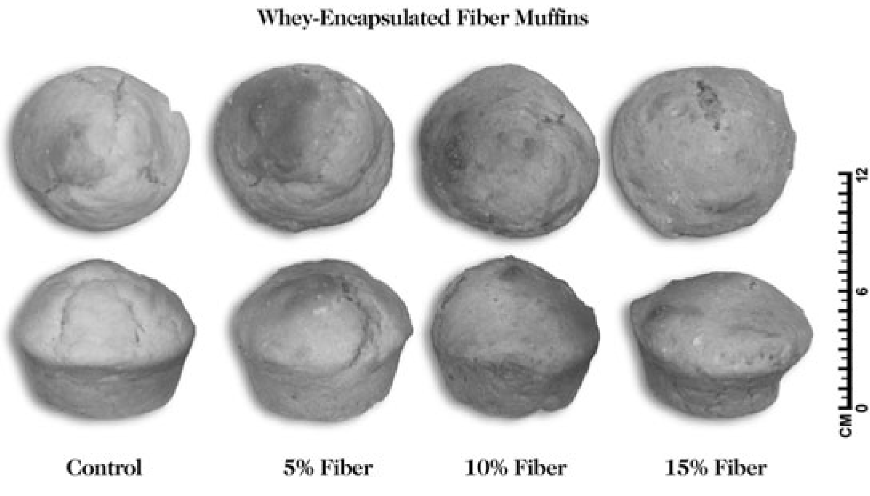

FIG. 4. PHOTOGRAPHIC IMAGE OF MUFFINS BAKED WITH UNCOATED WHEAT BRAN (CONTROL) AND THREE SELECTED AMOUNTS OF MILK PROTEIN-COATED WHEAT BRAN

darker than the control, but was lighter in color at 15 wt %. At both the 5 and 15 wt % amounts, the muffin containing protein-coated wheat bran was lighter in color than control muffins or the NCF. There was an anomalous result at the 10% level where muffins containing the protein-coated fiber were darker than the control muffins. The interaction of wheat bran, protein and water might explain these differences. No apparent trend in color difference was determined.

In general, cookies and muffins containing wheat bran products of both kinds were harder than the control, except at the 5 wt % amounts which were slightly, but not significantly, softer than the control. The trend of increased hardness with increasing addition of wheat bran reported previously was observed.

Cookies and muffins containing wheat bran products were generally larger in volume than the controls. Unlike cookies, muffins are high-moisture products, and both forms of wheat bran used (MPCF or NCF) absorbed more moisture and increased in displaced volume compared to the control (Table 4). The increase in volume may be a result of swollen wheat bran fibers from increased moisture.

DISCUSSION

A reduction in the water absorption capacity of wheat bran coated with the milk protein was observed. The NCF, like MPCF, composed of relatively fine particles (<149 microns), absorbed more water than the protein-coated fiber. Coating of wheat bran with proteins creates a film and reduces the amount of water absorbed by the bran. The MPCF contained more protein than the NCF, and increased the whey protein content in cookies and muffins. The addition of MPCF increased cookie and muffin volume, contrary to previous studies which reported a decrease in volume, especially when proteins from whey concentrates were added in quantities greater than 2 wt % (Guy *et al.* 1974). Denaturation or modification of whey protein improves baking quality (Sanchez *et al.* 1984). The spray-drying process used to make MPCF denatured the whey proteins selected to coat the wheat bran fibers. The milk proteins were denatured in the process of coating the wheat bran and resulted in improved cookie and muffin characteristics.

The absorption of water in cookies and muffins formulated with both NCF and MPCF affected the physical characteristics of the dough and the baked cookies and muffins. Water content of baked cookies and muffins is important because of gelatinization of starch during heating. Starch gelatinization during baking occurs over a narrow water activity range (Ablett *et al.* 1985). The addition of wheat bran into bread dough systems increased water absorption (Zhang and Moore 1997). Added wheat bran can be detrimental to loaf volume (Cadden 1987). Addition of between 5- to 15-g sugarcane fiber into wheat flour reduced the expansion, breaking strength, stickiness of dough, volume and firmness of bread loaf significantly (Sangnark and Noomhorm 2004).

The color of baked cookies and muffins containing wheat bran became darker as the amount of bran added increases. Zhang and Moore (1997) reported a darkening of the color of dough when wheat bran was added.

Darkening of baked sugar-snap cookies by the presence of wheat bran was reported (Vratanina and Zabik 1978). Adding wheat bran fiber darkened cookies and muffins, except in muffins containing 5 and 15 wt % MPCF. The darkening of baked products containing wheat bran can be alleviated by coating the DF with milk proteins.

Firmness of baked goods is an indicator of their textural quality. Vratanina and Zabik (1978), reported an increase in crispness of high-fiber cookies associated with increasing hardness. Decreasing hardness (breaking force) indicates a less crisp cookie. In this study, cookies baked with MPCF were firmer and crispier.

Adding DF to baked cookies and muffins is known to decrease the volume. Zhang and Moore (1997) reported that wheat bran in bread reduced the volume. In this study, adding fiber increased cookie volume. The volume of muffin products decreased when NCF was added, but increased at 5 and 10% addition of MPCF to muffins. The exception was at 15% where volume decreased.

The increase or decrease in volume of muffins containing wheat bran may be related to moisture absorption by the wheat bran. In dry cookies, volume increases because the fiber acts as spacers in the structure (Fig. 3). In high-moisture muffins, the fiber acts as a sponge to absorb the surrounding water, thereby reducing the volume of the muffins. By coating the wheat bran fiber with whey protein, the volume and moisture of muffins increase.

There is a wide acceptance of baked cookies and muffins containing wheat bran for health appeal. Muffins containing up to 30 wt % wheat bran was rated as acceptable by a trained sensory panel (Golden *et al.* 1995). Cookies containing 20 wt % wheat bran were acceptable to a consumer panel (Vratanina and Zabik 1978). Another consumer panel rated the sensory properties of cookies containing wheat bran as acceptable, identifying a smoother crust and a less gritty mouthfeel (Zhang and Moore 1997). It is expected that cookies and muffins containing milk protein-coated wheat bran will be acceptable to consumers.

CONCLUSIONS

Functionality of wheat bran was improved by coating with milk proteins. Reduction in volume, a negative effect typically associated with adding wheat bran to baked goods such as muffins, was mitigated by the coating process. Muffin volume increased 12 to 17%. Also, the textural properties of baked cookies and muffins such as hardness improved as the protein-coated wheat bran was added, making crispier cookies and softer muffins. By minimizing the negative effects on quality of incorporating fiber in foods, more fiber-enriched baked goods can be provided to consumers.

ACKNOWLEDGMENTS

The authors thank Mr. Richard Stoler for assistance with the texture analysis, Ms. Wendy Iwanshyn for preparing specimens for protein coating and Ms. Elena Dreyzin for baking the cookies and muffins.

REFERENCES

AACC. 1983. AACC Method 10-50D, Revised 10/3/84. In *Approved Methods of the American Association of Cereal Chemists*, Vol. 1 (B. Grami, ed.) American Association of Cereal Chemists, St. Paul, MN.

ABLETT, S., ATTENBURROW, G.E. and LILLFORD, P.J. 1985. The significance of water in the baking process. In *Chemistry and Physics of Baking* (J.M.V. Blanshard, P.J. Frazier and T. Galliard, eds.) pp. 30–41, The Royal Society of Chemistry, London, England.

AMERICAN DIETETIC ASSOCIATION POSITION STATEMENT. 1993. Health implications of dietary fiber. J. Am. Diet. Assoc. *93*, 1446–1447.

AOAC. 2000. *Official Methods of Analysis*, 14th ed. Association of Official Analytical Chemists, Washington, DC.

BOURNE, M.C. 1978. Texture profile analysis. Food Technol. *32*, 62–66.

BRENNAN, C.S., KURI, V. and TUDORICA, C.M. 2004. Inulin-enriched pasta: Effects on textural properties and starch degradation. Food Chem. *86*, 189–193.

CADDEN, A. 1987. Comparative effects of particle size reduction on physical structure and water binding properties of several plant fibers. J. Food Sci. *52*(6), 1595–1599, 1631.

DELLO STAFFOLO, M., BERTOLA, N., MARTINO, M. and BEVILACQUA, A. 2004. Influence of dietary fiber addition on sensory and rheological properties of yogurt. Int. Dairy J. *14*, 263–268.

GOLDEN, J.S., TOMA, R.B., TUVESON, R.V. and KELLETT, C.E. 1995. A comparative evaluation on high fiber muffins. Ecology Food Nutr. *33*, 195–202.

GUY, E.J., VETTEL, H.E. and PALLANSCH, M.J. 1974. Effect of cheese whey protein concentrate on the baking quality and rheological characteristics of sponge doughs made from hard red spring wheat flour. Cereal Sci. Today *19*(12), 551–556.

KRITCHEVSKY, D. 1977. Cereal fiber and lipidemia. Cereal Foods World *42*(2), 81–85.

LAI, C.S., HOSENEY, R.C. and DAVIS, A.B. 1989. Effects of wheat bran in breadmaking. Cereal Chem. *66*(3), 217–219.

SANCHEZ, H.D., DE LA TORRE, M.A., OSCELLA, C.A., MANUCUELLO, J.C. and FABRE, H.C. 1984. Whey protein concentrates in baking. I. Effect on rheological properties. Bakers Digest *58*(5), 18–20.

SANGNARK, A. and NOOMHORM, A. 2003. Effect of particle sizes on functional properties of dietary fibre prepared from sugarcane bagasse. Food Chem. *80*, 221–229.

SANGNARK, A. and NOOMHORM, A. 2004. Effect of dietary fiber from sugarcane bagasse and sucrose on dough and bread properties. Lebensm.-Wiss. Technol. *37*, 697–704.

SLAVIN, J.L. 2005a. Dietary fiber: Classification, chemical analyses, and food sources. J. Am. Diet. Assoc. *87*(9), 1164–1168, 1171.

SLAVIN, J.L. 2005b. Dietary fiber and body weight. Nutrition *21*, 411–418.

STRANGE, E.D. and KONSTANCE, R.P. 1991. A rapid method for laboratory preparation of high solids casein and caseinate dispersions. J. Dairy Sci. *74*, 1181–1186.

VRATANINA, D.L. and ZABIK, M.E. 1978. Dietary fiber sources for baked products: Bran in sugar-snap cookies. J. Food Sci. *43*(5), 1590–1594.

WOLK, A., MANSON, J.E., STAMPFER, M.J., HU, F.B., SPIEZER, F.E., HENNEKSENS, C.H. and WILLETT, W.C. 1999. Long-term intake of dietary fiber and decreased risk of coronary heart disease among women. JAMA *281*(21), 1998–2004.

ZHANG, D. and MOORE, W.R. 1997. Effect of wheat bran particle size on dough rheological properties. J. Sci. Food Agric. *74*, 490–496.